



## **NCI Division of Cancer Biology Strategic Workshop**

### **Prospective Outlook of Mechanics in Oncology**

#### **Executive Summary, Agenda, and Participants List**

September 11-12, 2014

NCI Shady Grove, Terrace Room TE406  
9609 Medical Center Drive, Rockville, MD 20850

Division of Cancer Biology  
National Cancer Institute  
National Institutes of Health  
U.S. Department of Health and Human Services

## EXECUTIVE SUMMARY

The National Cancer Institute (NCI) Physical Sciences in Oncology Initiative within the Division of Cancer Biology (DCB) aims to enrich our current understanding of cancer by facilitating the formation of teams of physical scientists and cancer researchers who work together to bring a novel “physical sciences perspective” to cancer biology. On September 11-12, 2014, DCB convened a Strategic Workshop: **Prospective Outlook of Mechanics in Oncology** to provide a status update of the field of cell and tissue mechanics in cancer biology and to address the prospect of using mechanical measurements as physical biomarkers for disease progression or treatment response.

The response of cancer cells and tissues to physical forces, pressures, or molecular tensions in the stromal microenvironment is a function of their inherent architectural and structural properties. Cell and tissue mechanics is defined as the physical properties, the strength of mechanical forces, and the resultant cell and tissue functional response. Mounting evidence suggests cell and tissue mechanics are significant contributors to the initiation and progression of cancer. The propagation of mechanical forces at cellular and tissue scales has been associated with numerous cell processes, including differentiation, migration, and proliferation. Changes to the physical properties of cells, extracellular matrix, or tissue during cancer progression perturb these mechanical forces and subsequently affect downstream cellular processes. Therefore, knowledge of the mechanisms involved in mechanical feedback loops and application of appropriate mechanical measurement tools may lead to new potential drug targets, diagnostic tools, and risk indicators in oncology. This workshop was designed to explore the latest research in the field of cell and tissue mechanics in cancer biology and identify opportunities as next steps for the field.

Workshop discussions centered around findings pertaining to the mechanical measurements of single cells, mechanical forces between neighboring cells, as well as between cells and their surrounding matrix. Presentations highlighted the effects of mechanical forces on cancer progression, correlations between cell mechanical properties and molecular expression pathways, and assessments of how changes in the extracellular matrix structure and physical properties may correlate with tumor progression. Two broad topics were identified as emerging areas for more development. These included (1) the interplay between mechanical forces and cancer pathways, and (2) the development of physical biomarkers for defining “signatures” of cancer progression. Below is a summary of the research results presented in the two highlighted topic areas and potential opportunities for moving the field forward.

### Interplay between mechanical forces and biological pathways

- Induction of mechanical pressure *in vivo* activates oncogenic signaling pathways in mouse models of cancer
- Mechanical stress in fibronectin induces expression of soluble factors that promote angiogenesis and tumor formation
- Pro-inflammatory pathways modulate matrix stiffness and drive tumor progression
- Dynamic shear forces and cellular crowding influence adhesion molecule-mediated migration of metastatic tumor cells in a 3D context
- Matrix stiffness affects the viscosity and elasticity of the cell nucleus, which leads to susceptibility of cells to DNA damage and activation of oncogenic signaling pathways

### Biophysical markers for tumor progression signatures and diagnostics

- Mechanophenotyping of circulating tumor cells (*i.e.*, cell size, contractility, deformability, morphology, adhesiveness) enables more sensitive, objective, and efficient diagnosis of tumor cell malignancy
- Mechanical waves in magnetic resonance elastography image tissue stiffness *in vivo* (human and mouse) and determine distinct tumor types based on tissue stiffness signatures

- Biomechanical measurements distinguish between cancerous and normal tissue by quantifying cell-cell adhesion/surface tension and cell stiffness from the single-cell scale to tissue scale
- Cell-matrix traction forces and adhesion strength measurements define adhesive force signatures that are unique to distinct cancer cell types (*e.g.*, tumor-initiating cells, cancer stem cells, cell subpopulations within a heterogeneous tumor)
- Collagen remodeling signatures defined by structural properties are potential prognostic indicators in cancer (*i.e.*, higher degree of collagen fiber alignment perpendicular to the tumor boundary is indicative of tumor progression)

#### Next steps to advance the field of cell and tissue mechanics

- Increased collaboration between the mechanics/mechanobiology and oncology communities in order to better identify immediate clinical needs as well as developing better methods for incorporating cell and tissue mechanical measurements into clinical practice
- Development of standardized cell lines and standardized synthetic matrix analogs with precise control over biophysical and biochemical properties to improve studies of cell-cell and cell-matrix mechanics in 3D cultures
- Development of more robust technologies to better understand the connection between mechanical forces and cellular processes such as molecular pathways and regulation, transcription, translation, genome editing, and phenotype
- Integration of measurements taken at different time- and length-scales into more comprehensive datasets and incorporating them with mathematical approaches; and the use of mathematical modeling to better understand the feedback loop of mechanical and biological information
- Better understanding of the effect of anti-cancer drugs, chemotherapy and radiation on the physical properties of the stroma
- Identification of new biomechanical markers that have prognostic value
- Addressing the dynamic complexity of cancer (*e.g.*, tumor heterogeneity, *etc.*) when developing new cell and tissue mechanics models
- Development of clinically relevant animal models for studying cell and tissue mechanics *in vivo*
- Incorporating physical factors in addition to stiffness, such as topology and spatial features within tumor tissues, to better understand the specific physical parameters and how they affect cancer biology.



## NCI Division of Cancer Biology Strategic Workshop

# Prospective Outlook of Mechanics in Oncology

September 11-12, 2014  
NCI Shady Grove, Terrace Room TE406  
9609 Medical Center Drive, Rockville, MD 20850

## AGENDA

---

### ***Meeting Objectives***

Over the last decade, mounting evidence has identified cell and tissue mechanics as a contributor in the initiation and progression of cancer. Mechanical forces exchanged at a cellular and tissue level have been associated with numerous cell processes, including differentiation, migration, proliferation, and adhesion. Changes to the physical properties of cells, extracellular matrix, or tissue during disease progression perturb these mechanical forces and subsequently affect downstream cellular processes. Early knowledge of the mechanisms involved in mechanical feedback loops and application of appropriate mechanical measurement tools may lead to new potential drug targets, diagnostic tools, and risk indicators in oncology.

This workshop will serve to provide a status of the field of cell and tissue mechanics in understanding cancer biology and the prospect of using mechanical measurements as physical biomarkers for disease progression or treatment response. Discussions will revolve around the mechanisms of cancer cell response to mechanical forces, the types of mechanical measurements that are appropriate for monitoring mechanical forces, and the potential translation of mechanical biomarkers.

---

### **Day 1: Thursday, September 11**

- |                       |   |
|-----------------------|---|
| 3:00 p.m. - 3:30 p.m. | <b>Security and Registration</b>  |
| 3:30 p.m. - 3:35 p.m. | <b>Welcome and Introductions</b><br>Larry A. Nagahara, Ph.D.<br>Associate Director, Division of Cancer Biology<br>National Cancer Institute   |
| 3:35 p.m. - 3:45 p.m. | <b>Workshop Goals</b><br>Nicole M. Moore, D.Sc.<br>Program Director, Division of Cancer Biology<br>National Cancer Institute  |
| 3:45 p.m. - 6:30 p.m. | <b>Session I: Quantifying Mechanical Forces</b><br>Moderator: Jennifer Couch, Ph.D.<br>Chief, Structural Biology and Molecular Applications Branch<br>Division of Cancer Biology<br>National Cancer Institute |

3:45 p.m. - 4:10 p.m.	<b>Cell and Tissue Mechanics</b> Josef Käs, Ph.D. Principal Investigator and Head, Soft Matter Physics Division, Institute of Experimental Physics 1 University of Leipzig
4:10 p.m. - 4:35 p.m.	<b>Fluid Stresses Govern 3D Cell Migration</b> Roger D. Kamm, Ph.D. Cecil and Ida Green Distinguished Professor of Biological and Mechanical Engineering Massachusetts Institute of Technology
4:35 p.m. -5:00 p.m.	<b>ECM Tension and Topology</b> Delphine Gourdon, Ph.D. Assistant Professor, Department of Materials Science and Engineering Cornell University
5:00 p.m. – 5:25 p.m.	<b>Integrin Tension and Cell Adhesion</b> Andrés Garcia, Ph.D. Rae S. and Frank H. Neely Chair and Regents' Professor, George W. Woodruff School of Mechanical Engineering Georgia Institute of Technology
5:25 p.m. - 6:30 p.m.	<b>Group Discussion</b>
6:30 pm - 7:00 p.m.	<b>Shuttle return for travelers to Gaithersburg Marriott Washingtonian Dinner (on own)</b>

## **Day 2: Friday, September 12**

7:30 a.m.	<b>Shuttle pickup for travelers at Gaithersburg Marriott Washingtonian</b>
8:15 a.m. - 8:20 a.m.	<b>Welcome Day 2</b> Nastaran Z. Kuhn, Ph.D. Program Director, Division of Cancer Biology National Cancer Institute
8:20 a.m. - 9:15 a.m.	<b>Session II: Standardizing Mechanics Measurements</b> Moderator: Nicole M. Moore, D.Sc. Program Director, Division of Cancer Biology National Cancer Institute
8:20 a.m. - 8:45 a.m.	<b>Summary of the UN of Cell Modulus Project</b> Denis Wirtz, Ph.D. Theophilus Halley Smoot Professor of Chemical and Biomolecular Engineering Johns Hopkins University
8:45 a.m. - 9:15 a.m.	<b>Group Discussion</b>
9:15 a.m. - 11:40 a.m.	<b>Session III: Biological Responses to Mechanical Forces</b> Moderator: Suresh Mohla, Ph.D. Associate Director, Division of Cancer Biology Chief, Tumor Biology and Metastasis Branch National Cancer Institute

9:15 a.m. - 9:40 a.m.	<b>Force Driven Tumorigenesis</b> Emmanuel Farge, Ph.D. Research Director INSERM Institute Curie
9:40 a.m. - 10:05 a.m.	<b>Biological Response to ECM Stiffness</b> Patricia Keely, Ph.D. Professor and Chair, Cell and Regenerative Biology University of Wisconsin – Madison
10:05 a.m. – 10:20 a.m.	<b>Break</b>
10:20 a.m. -10:45 a.m.	<b>Mechanically Coupled Systems of Mammary Acini</b> Jan Liphardt, Ph.D. Associate Professor of Bioengineering Stanford University
10:45 a.m. -11:10 a.m.	<b>Nuclear Mechanics and DNA Stability</b> Dennis Discher, Ph.D. Robert D. Bent Chaired Professor, School of Engineering and Applied Science University of Pennsylvania
11:10 a.m. - 11:40 a.m.	<b>Group Discussion</b>
11:40 a.m. - 1:00 p.m.	<b>Lunch</b> (on own)
12:15 p.m. - 1:00 p.m.	<b>Poster Viewing in Terrace Room TE406</b> <ol style="list-style-type: none"> <li> <b>Dexamethasone Increases Tissue Surface Tension and Reduces Dispersal of Primary Glioblastoma Cells</b>  Ramsey Foty, Ph.D., Associate Professor, Biomedical Engineering, Rutgers University- Robert Wood Johnson Medical School, Department of Surgery </li> <li> <b>Mechanobiology of the Cellular Glycocalyx</b>  Matthew Paszek, Ph.D. Assistant Professor, Chemical and Biomolecular Engineering, Cornell University </li> <li> <b>Screening Cancer Cell Mechanotype by Parallel Microfiltration</b>  Amy Rowat, Ph.D., Principal Investigator, Integrative Biology and Physiology, University of California, Los Angeles </li> <li> <b>Biomaterials Based Adaptive Tumor microenvironments for Lymphoma</b>  Ankur Singh, Ph.D. Assistant Professor, Mechanical and Aerospace Engineering, Cornell University </li> <li> <b>Extracting Quantitative Data from AFM Indentations on Soft, Heterogeneous Biomaterials</b>  J. Rory Staunton, Research Assistant, Center for Biological Physics, Arizona State University </li> <li> <b>MDA-MB-231 Cells Stiffen During Invasion into 3D Collagen I Matrices</b>  J. Rory Staunton, Research Assistant, Center for Biological Physics, Arizona State University </li> </ol>
1:00 p.m. - 2:45 p.m.	<b>Session IV: Translational Potential of Mechanics in Oncology</b> Moderator: Jerry S.H. Lee, Ph.D. Deputy Director, Center for Strategic Scientific Initiatives National Cancer Institute

1:00 p.m. - 1:25 p.m.	<b>Mechanical Drug Targets and Prognostic Indicators</b> Valerie Weaver, Ph.D. Professor of Surgery, Anatomy, Bioengineering & Tissue Regeneration and Therapeutic Sciences Director, Center for Bioengineering and Tissue Regeneration University of California, San Francisco
1:25 p.m. - 1:50 p.m.	<b>Diagnosis of Malignant Pleural Effusions by Single-Cell Mechanophenotyping</b> Dino DiCarlo, Ph.D. Associate Professor, Department of Bioengineering University of California, Los Angeles
1:50 p.m. - 2:15 p.m.	<b>Magnetic Resonance Elastography</b> Richard Ehman, M.D. Professor of Radiology Mayo Clinic
2:15 p.m. - 2:45 p.m.	<b>Group Discussion</b>
2:45 p.m. – 2:55 p.m.	<b>Break</b>
2:55 p.m. - 3:30 p.m.	<b>Session V: Overview and Future Directions</b> Moderators: Nicole M. Moore, D.Sc. Program Director, Division of Cancer Biology National Cancer Institute  Nastaran Z. Kuhn, Ph.D. Program Director, Division of Cancer Biology National Cancer Institute
3:30 p.m.	<b>Adjourn</b>

**National Cancer Institute  
Strategic Workshop**

**Prospective Outlook of Mechanics in Oncology  
September 11-12, 2014**

**PARTICIPANTS**

---

**Atef Asnacios, Ph.D.**

Deputy Director  
Department of Physics  
Université Paris Diderot  
atef.asnacios@univ-paris-diderot.fr

**Marshall Colville**

Research Assistant  
Department of Chemical and Biomolecular  
Engineering  
Cornell University  
mjc449@cornell.edu

**Howland Crosswell, M.D.**

CMO  
KIYATEC, Inc.  
hal.crosswell@kiyatec.com

**Dino Dicarlo, Ph.D.**

Associate Professor  
Department of Bioengineering  
University of California, Los Angeles  
dicarlo@seas.ucla.edu

**Dennis E. Discher, Ph.D.**

Robert D. Bent chaired Professor  
Chemical and Biomolecular Engineering (CBE)  
Bioengineering (BE)  
Mechanical Engineering and Applied Mechanics  
(MEAM)  
School of Engineering and Applied Science  
University of Pennsylvania  
discher@seas.upenn.edu

**Pauline Durand**

Research Assistant  
Department of Physics  
University of Paris, Diderot  
pauline.durand@univ-paris-diderot.fr

**Richard L. Ehman, M.D.**

Professor  
Department of Radiology  
Mayo Clinic  
ehman.richard@mayo.edu

**Andrew Ekpenyong, Ph.D.**

Assistant Professor  
Department of Physics  
Creighton University  
AndrewEkpenyong1@creighton.edu

**Emmanuel Farge, Ph.D.**

Research Director 2nd class INSERM  
Mechanics and Genetics of Embryonic and Tumoral  
Development Research Group  
Department of Physical Chemistry  
Institute Curie  
emmanuel.farge@curie.fr

**Claudia Fischbach-Teschl, Ph.D.**

Associate Professor  
Department of Biomedical Engineering  
Cornell University  
CF99@cornell.edu

**Ramsey Foty, Ph.D.**

Associate Professor  
Department of Surgery  
Rutgers-Robert Wood Johnson Medical School  
fotyra@rutgers.edu

**Andres Garcia, Ph.D.**

Woodruff Professor  
Woodruff School of Mechanical Engineering  
Chair, Interdisciplinary Graduate Bioengineering  
Program  
Georgia Institute of Technology  
andres.garcia@me.gatech.edu



**Delphine Gourdon, Ph.D.**

Assistant Professor  
Department of Materials Science and Engineering  
Cornell University  
dg434@cornell.edu

**Bumsoo Han, Ph.D.**

Associate Professor of Mechanical Engineering, by  
courtesy in Biomedical Engineering  
School of Mechanical Engineering  
Weldon School of Biomedical Engineering  
Birck Nanotechnology Center  
Purdue University  
bumsoo@purdue.edu

**Roger Kamm, Ph.D.**

Cecil and Ida Green Distinguished Professor of  
Biological and Mechanical Engineering  
Departments of Biological and Mechanical  
Engineering  
Massachusetts Institute of Technology  
rdkamm@mit.edu

**Josef Käs, Ph.D.**

Principal Investigator and Head  
Soft Matter Physics Division, Institute of Experimental  
Physics 1  
University of Leipzig  
jkaes@physik.uni-leipzig.de

**Patricia Keely, Ph.D.**

Professor and Chair  
Cell and Regenerative Biology  
University of Wisconsin-Madison  
pjkeely@wisc.edu

**Philip R. LeDuc, Ph.D.**

Professor  
Department of Mechanical Engineering  
Carnegie Mellon University  
prl@andrew.cmu.edu

**Jan Liphardt, Ph.D.**

Associate Professor, Bioengineering  
Member, Stanford Cancer Institute  
Director and Principal Investigator, Bay Area Physical  
Sciences Oncology Center  
Department of Bioengineering  
Stanford University  
jan.liphardt@stanford.edu

**Gregory Longmore, Ph.D.**

Professor of Medicine, Cell Biology and Physiology  
Director, ICCE Institute  
Washington University School of Medicine  
glongmor@dom.wustl.edu

**Wolfgang Losert, Ph.D.**

Professor of Physics  
Associate Dean for Research, CMNS  
Director, Partnership for Cancer Technology  
University of Maryland  
wlosert@umd.edu

**Thomas Neumann, M.D.**

President and CEO  
Nortis, Inc.  
neumann@nortisbio.com

**Catherine Park, M.D.**

Associate Professor  
Department of Clinical Radiation Oncology  
University of California, San Francisco  
cpark@radonc.ucsf.edu

**Matthew J. Paszek, Ph.D.**

Assistant Professor  
Department of Chemical and Biomolecular  
Engineering  
Cornell University  
mjp31@cornell.edu

**Yeh-Chuin Poh, Ph.D.**

Postdoctoral Fellow  
Massachusetts Institute of Technology  
yehchuin@gmail.com

**Robert Ros, Ph.D.**

Professor  
Department of Physics  
Arizona State University  
Robert.Ros@asu.edu

**Amy Rowat, Ph.D.**

Assistant Professor  
Department of Integrative Biology and Physiology  
University of California, Los Angeles  
rowat@ucla.edu

**Mathias Sander,**

Research Assistant  
Laboratory for Experimental Biophysics  
Saarland University  
m.sander@physik.uni-saarland.de

**Victoria Seewaldt, M.D.**

Professor of Medicine  
Department of Medicine - Oncology  
Duke University  
victoria.seewaldt@duke.edu

**Ankur Singh, Ph.D.**

Assistant Professor  
Sibley School of Mechanical and Aerospace  
Engineering  
Cornell University  
as2833@cornell.edu

**Igor Sokolov, Ph.D.**

Professor  
Department of Mechanical Engineering  
Adjunct Professor, Department of Biomedical  
Engineering  
Adjunct Professor, Department of Physics  
Bernard M. Gordon Senior Faculty Fellow  
Tufts University  
Igor.Sokolov@tufts.edu

**Jack 'Rory' Staunton**

Research Assistant  
Department of Physics  
Arizona State University  
jrstaunt@asu.edu

**Andreea Trache, Ph.D.**

Associate Professor  
Department of Biomedical Engineering  
Texas A&M University  
trache@tamu.edu

**Valerie M. Weaver, Ph.D.**

Professor  
Departments of Surgery, Anatomy, and  
Bioengineering & Therapeutics Sciences  
Director, Center for Bioengineering & Tissue  
Regeneration  
Co-Director, Bay Area PSOC  
Co-Director, UCSF Brain TMEN Program  
University of California, San Francisco  
Valerie.Weaver@ucsfmedctr.org

**Denis Wirtz, Ph.D.**

Vice Provost for Research  
Theophilus Halley Smoot Professor  
Department of Chemical and Biomolecular  
Engineering  
Johns Hopkins University  
wirtz@jhu.edu

**Federal Attendees****Lokesh Agrawal, Ph.D.**

Program Director  
Biorepositories and Biospecimen Research Branch,  
Cancer Diagnosis Program, Division of Cancer  
Treatment and Diagnosis  
National Cancer Institute  
lokesh.agrawal@nih.gov

**Greg Baxter, Ph.D.**

Senior Scientist  
CCS Associates  
gbaxter@ccsainc.com

**Michelle Berny-Lang, Ph.D.**

Program Director  
Center for Strategic Scientific Initiatives  
National Cancer Institute  
michelle.berny-lang@nih.gov

**Clara Bodelon, Ph.D.**

Fellow  
Hormonal and Reproductive Epidemiology Branch  
National Cancer Institute  
clara.bodelon@nih.gov

**Lingfeng Chen, Ph.D.**

Adjunct Scientist  
Lippincott-Schwartz Lab  
*Eunice Kennedy Shriver* National Institute of Child  
Health and Human Development  
chenl15@nih.gov

**Jennifer Couch, Ph.D.**

Chief  
Structural Biology and Molecular Applications Branch  
Division of Cancer Biology  
National Cancer Institute  
jennifer.couch@nih.gov

**Donald Coppock, Ph.D.**

Scientific Review Officer  
Research Technology and Contract Review Branch  
Division of Extramural Activities  
National Cancer Institute  
coppockdl@mail.nih.gov

**Tony Dickherber, Ph.D.**

Program Director  
Center for Strategic Scientific Initiatives  
National Cancer Institute  
tony.dickherber@nih.gov

**Brian DuChes, Ph.D.**

Fellow  
Cell Biology Section  
National Institute of Dental and Craniofacial Research  
brian.duches@nih.gov

**Dan Gallahan, Ph.D.**

Division Deputy Director  
Division of Cancer Biology  
National Cancer Institute  
gallahad@mail.nih.gov

**Gretchen L. Gierach, Ph.D., M.P.H.**

Investigator  
Hormonal and Reproductive Epidemiology Branch  
Division of Cancer Epidemiology & Genetics  
National Cancer Institute  
gierachg@mail.nih.gov

**Emily Greenspan, Ph.D.**

Program Director  
Center for Strategic Scientific Initiatives  
National Cancer Institute  
emily.greenspan@nih.gov

**Todd Haim, Ph.D.**

Program Director  
Small Business Innovation Research  
National Cancer Institute  
todd.haim@nih.gov

**Toby Hecht, Ph.D.**

Associate Director  
Translational Research Program  
Division of Cancer Treatment and Diagnosis  
National Cancer Institute  
toby.hecht@nih.gov

**Stephen M. Hewitt, M.D., Ph.D.**

Staff Clinician  
Laboratory of Pathology  
Center for Cancer Research  
National Cancer Institute  
hewitts@mail.nih.gov

**Susan Keating, Ph.D.**

Senior Scientist  
CCS Associates  
skeating@ccsainc.com

**Chris Kelley, Ph.D.**

Director  
Division of Discovery Science & Technology  
National Institute of Biomedical Imaging and  
Bioengineering  
christine.kelley@nih.gov

**Warren Kibbe, Ph.D.**

Director  
CBIIT, OD  
National Cancer Institute  
warren.kibbe@nih.gov

**Randy Knowlton, Ph.D.**

Program Director  
Structural Biology and Molecular Applications Branch  
Division of Cancer Biology  
National Cancer Institute  
knowltoj@mail.nih.gov

**Nastaran Z. Kuhn, Ph.D.**

Program Director  
Structural Biology and Molecular Applications Branch  
Division of Cancer Biology  
National Cancer Institute  
nas.kuhn@nih.gov

**Jerry Lee, Ph.D.**

Deputy Director  
Center for Strategic Scientific Initiatives  
National Cancer Institute  
jerry.lee@nih.gov

**Shadi Mamaghani, Ph.D.**

Sr. Scientific Advisor  
Office of the Director  
National Institute of Biomedical Imaging and  
Bioengineering  
shadi.mamaghani@nih.gov

**Susan McCarthy, Ph.D.**

Program Director  
National Cancer Institute  
mccarths@mail.nih.gov

**Suresh Mohla, Ph.D.**

Associate Director and Chief  
Tumor Biology and Metastasis Branch  
Division of Cancer Biology  
National Cancer Institute  
suresh.mohla@nih.gov

**Nicole Moore, Sc.D.**

Program Director  
Structural Biology and Molecular Applications Branch  
Division of Cancer Biology  
National Cancer Institute  
nicole.moore@nih.gov

**Mahua Mukhopadhyay, Ph.D.**

Program Director  
Early Embryonic Development  
Developmental Biology and Structural Variation  
Branch (DBSVB)  
*Eunice Kennedy Shriver* National Institute of Child  
Health and Human Development  
mukhopam@mail.nih.gov

**Maeve Mullooly, Ph.D.**

Visiting Fellow  
Cancer Prevention Fellowship Program  
National Cancer Institute  
maeve.mullooly@nih.gov

**Larry Nagahara, Ph.D.**

Division Associate Director  
Division of Cancer Biology  
National Cancer Institute  
larry.nagahara@nih.gov

**Carole A. Parent, Ph.D.**

Deputy Chief  
Laboratory of Cellular and Molecular Biology  
Center for Cancer Research  
National Cancer Institute  
ParentC@mail.nih.gov

**Teresa Schuessler, M.S.**

Health Communications Fellow  
Division of Cancer Biology  
National Cancer Institute  
teresa.schuessler@nih.gov

**Caroline Sigman, Ph.D.**

President and CEO  
CCS Associates  
csigman@ccsainc.com

**Dinah Singer, Ph.D.**

Director  
Division of Cancer Biology  
National Cancer Institute  
singerd@mail.nih.gov

**Brian Sorg, Ph.D.**

Program Director  
Cancer Diagnosis Progra  
Division of Cancer Treatment and Diagnosis  
National Cancer Institute  
brian.sorg@nih.gov

**Kandice Tanner, Ph.D.**

Investigator  
Laboratory of Cell Biology  
Center for Cancer Research  
National Cancer Institute  
kandice.tanner@nih.gov

**Katrina Theisz, M.S.**

Operations Coordinator  
Structural Biology and Molecular Applications Branch  
Division of Cancer Biology  
National Cancer Institute  
katrina.theisz@nih.gov

**Jim Tricoli, Ph.D.**

Chief  
Cancer Diagnosis Program  
Division of Cancer Treatment and Diagnosis  
National Cancer Institute  
james.tricoli@nih.gov

**Jessica Tucker, Ph.D.**

Program Director  
Division of Discovery Science & Technology  
National Institute of Biomedical Imaging and  
Bioengineering  
jessica.tucker@nih.gov

**Keren Witkin, Ph.D.**

Program Director  
Cancer Cell Biology Branch  
Division of Cancer Biology  
National Cancer Institute  
keren.witkin@nih.gov

**Elisa Woodhouse, Ph.D.**

Program Director  
Tumor Biology and Metastasis Branch  
Division of Cancer Biology  
National Cancer Institute  
woodhousee@mail.nih.gov